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Simulating Bridge Crossings

by

Russell Hepler

Report Date

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13. ABSTRACT (*Maximum 200 words*) Study to determine the feasibility and advisability of alternate methods of durability testing of military bridges. Objective was to reduce bridge test costs by substituting simulated crossings for a portion of the field crossings test used to assess the bridge durability requirement of 5000 crossings.

A viable test procedure was developed which uses hydraulic actuators that apply cyclic loads to bridge prototypes to simulate tank crossings. The simulation test method outlined in this paper provides the following:

1. Significant savings in cost and time over field crossings.
2. A method for using the hydraulic actuators to create stresses in the bridge prototypes equal to the stresses created by tank crossings.
3. A method of incorporating strain data found during field crossings to ensure that the loads applied during the simulation are representative of the loads that occur during field crossings.
4. A consistent test procedure that is not altered based on the bridge design being tested. This approach eliminates the errors that might be caused by subjective evaluations from engineers' analysis of bridge designs.

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Simulating Bridge Crossings

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Executive Summary

Belvoir RDE Center (Belvoir) and Comb... Systems Test Activity (CSTA) conducted a joint study to determine the feasibility and advisability of alternate methods of durability testing of military bridges. The objective was to reduce bridge test costs by substituting simulated crossings for a portion of the field crossings test used to assess the bridge durability requirement of 5000 crossings.

A viable test procedure was developed which uses the loading equipment in the Belvoir bridge hangar to simulate tank crossings. The simulation test method outlined in this paper provides the following:

1. Significant savings in cost and time over field crossings.

2. A method for using the bridge hangar equipment to create stresses in the bridge prototypes equal to the stresses created by tank crossings.

3. A method of incorporating strain data found during field crossings to ensure that the loads applied during the simulation are representative of the loads that occur during field crossings.

4. A consistent test procedure that is not altered based on the bridge design being tested. This approach eliminates the errors that might be caused by subjective evaluations from engineers' analysis of bridge designs.

For the Heavy Assault Bridge (HAB) durability assessment, it is recommended that 2000 field crossings be performed on each of the HAB candidate designs followed by 3000 equivalent crossings under the load apparatus at Belvoir.

Recommendations for further research are provided.

STUDY GROUP MEMBERS

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Introduction

A study group was formed to research alternate methods of testing military bridges. The premise of the research was that the test for bridge durability might be accomplished in a way other than the expensive and time consuming method of driving actual 70 ton tanks across a bridge as many as 5000 times.

The study group was aware of industry programs to improve highway bridge designs through lab testing of the new designs. We sought to research methods currently used for other bridge systems to see if they had applicability to military assault bridges. Our research methods were: search the literature, talk to experts in the fatigue field, and combine the testing experience of the government testers at Combat Systems Test Activity (CSTA) with the bridge design experience of the engineers at Belvoir RDE Center.

Our first fatigue consultant was Mr. Donald Webber, the British Army's expert in bridging whose work in fatigue aspects of bridge design is extensively published (see Appendix A). Mr. Webber provided the study group with valuable insight into the British military bridge testing programs. Our second consultant was Dr. Wallace Sanders, Professor of Civil Engineering at Iowa State University. A list of his publications, found in Appendix A, demonstrates his extensive experience with fatigue in bridges. Dr. Sanders is especially knowledgeable in fatigue related to aluminum structures. Military bridges are almost exclusively fabricated from aluminum because of the weight saving necessities. Aluminum reacts significantly different than steel in many aspects, thus a special knowledge of aluminum is essential. Each consultant provided written feedback to the study group which is available upon request.

The combined experience of consultant engineers, the test engineers of the Combat Systems Test Activity (CSTA), and the bridge engineers of Belvoir helped to ensure that we were including all important aspects of bridge field operation while at the same time confirming that the simulated test would be sufficiently rigorous on the bridges.

Research Paper Goals

The two goals of the research paper are as follows:

1. Research theories to see if bridge durability testing is feasible through simulated loading techniques.

2. Propose a practical test for simulating loadings using the load frame equipment available at the Belvoir RDE Center Bridge Hangar.

To further expound on the goals, we sought a method to realistically duplicate the loads experienced by a bridge in field tests through applying loads on a Load Frame, in effect, simulating tank crossing loads. If simulation proved to be viable in theory, the second goal of the study was to propose a test program using the equipment available in the Belvoir Bridge Hangar. Figure 1 describes the load frame apparatus.

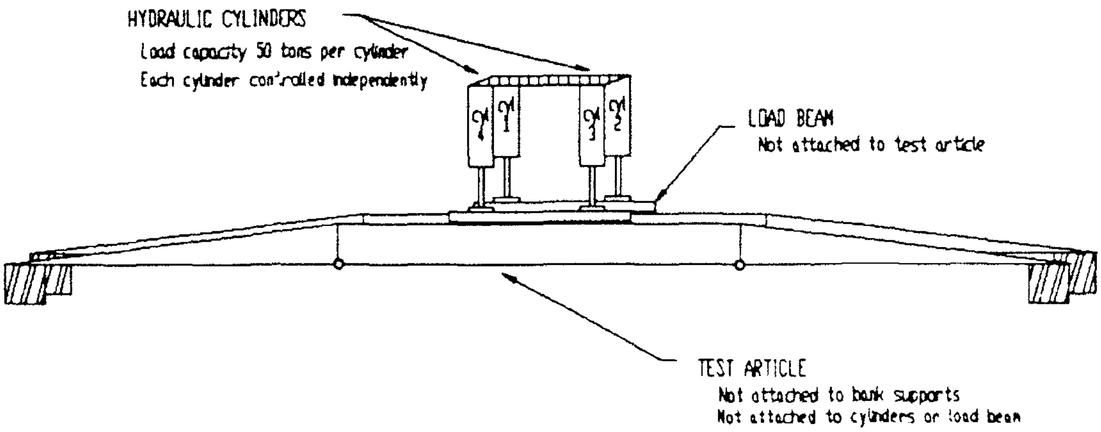

Figure 1. Load Frame Schematic

HAB Program Adds Realism

Contributing to an ongoing Army test program provided the study group with a reality check. We were fortunate to be involved with an actual Army program with actual equipment to force us into clear, practical thinking which greatly facilitated our planning efforts. The Army program was the evaluation test of the Heavy Assault Bridge (HAB). We had the task of not only developing a theoretical basis for a load frame test, but we had to flesh out the details sufficiently to describe an actual test using available equipment and data.

The HAB is a competitive program between three different assault bridge designs (see Figure 2a-d). The HAB systems shown in Figure 2a, are currently undergoing field tests at Aberdeen Proving Grounds (APG), Maryland. Strain data is available from actual tank crossings performed at APG. As shown in Figures 2a through 2d, the three designs have different characteristics. In our effort to develop a proposed simulation test, we considered the fairness of the test to each design and we sought to develop a test that would be equally rigorous on each design. If we designed a test that only loaded the bridges at midspan, for instance, it would likely be tougher on the bridge designs with connection points at midspan and less rigorous on the design with no connection point at midspan.

Because fairness was an essential element in the simulation, we sought a test approach that involved no subjective evaluation from engineers. We wanted to avoid a test approach that was altered according to the bridge designs involved. In other words, we attempted to develop a "black box" approach to the simulation using feedback from the field testing as much as possible to enhance test realism.

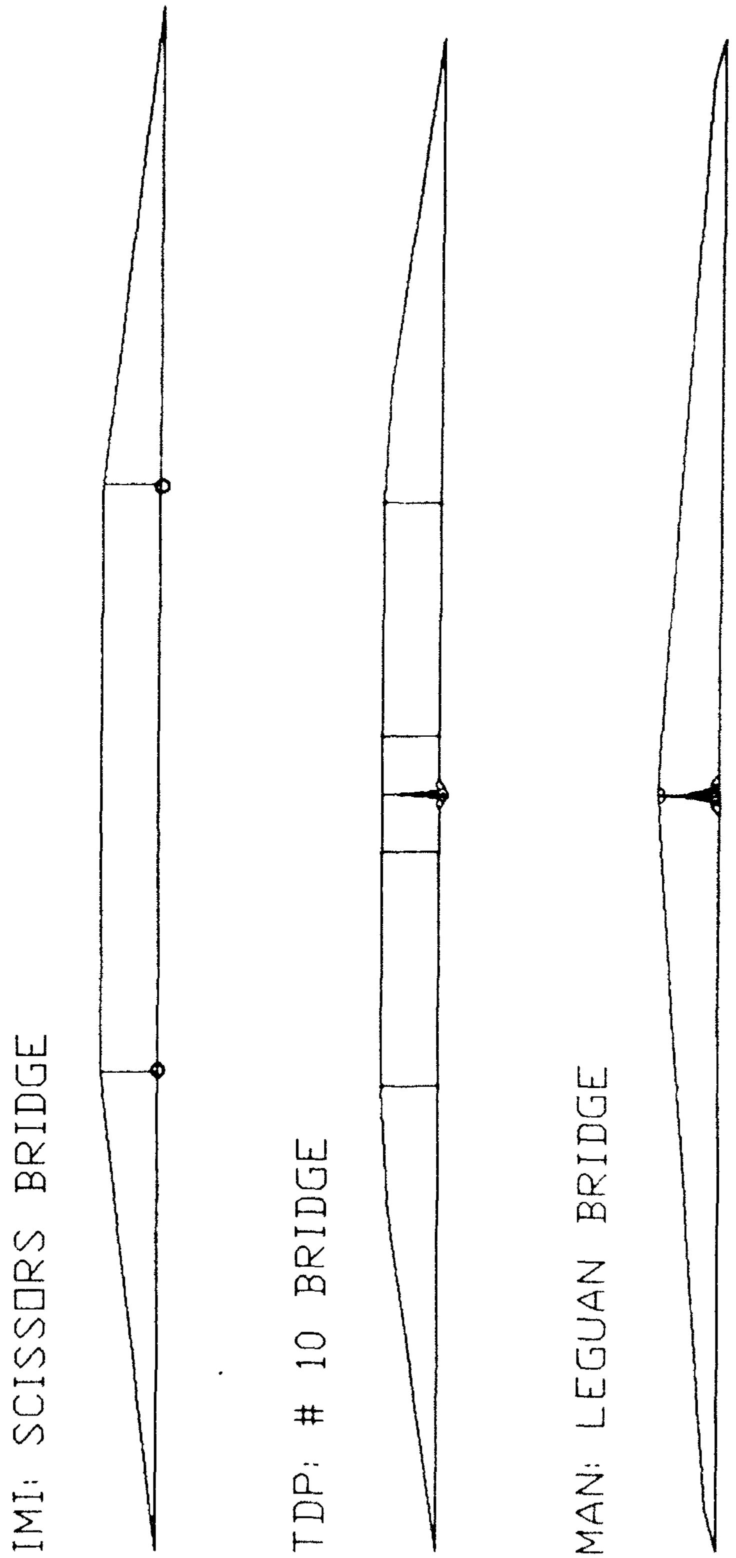

Figure 2a. HAB Candidates

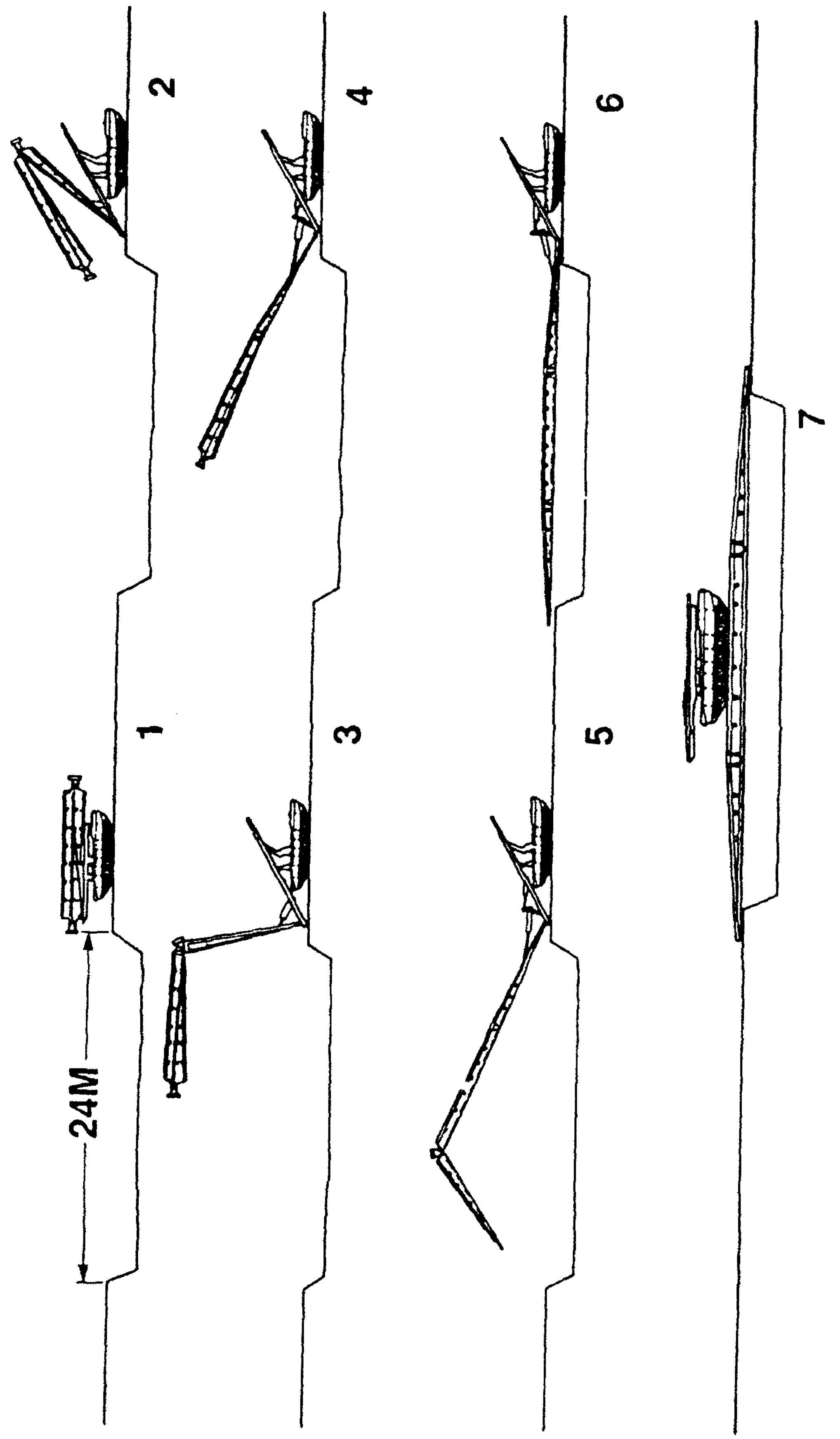

Figure 2b. Scissor HAB Launch Procedures

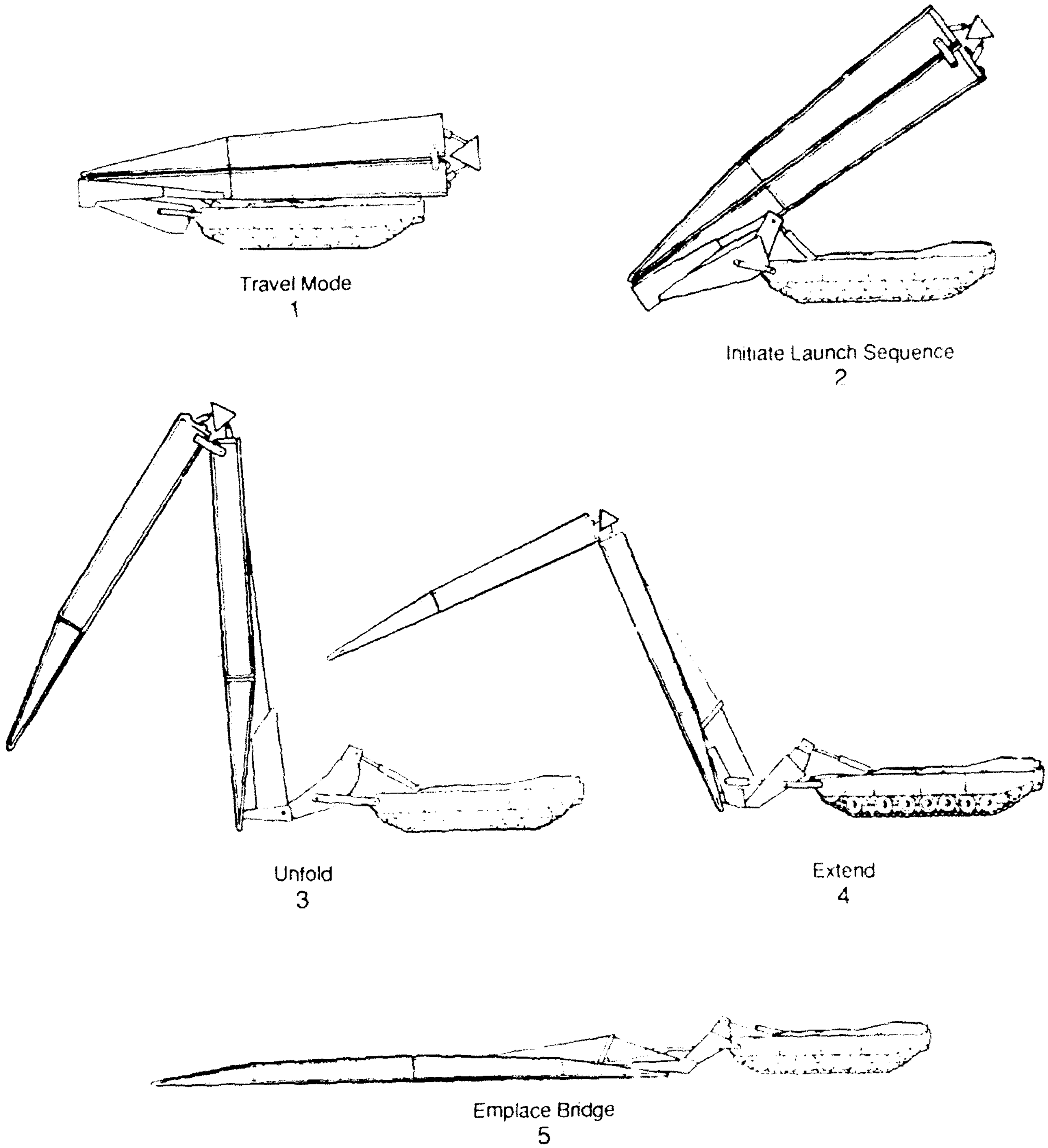

Figure 2c. No. 10 HAB Launch Procedures

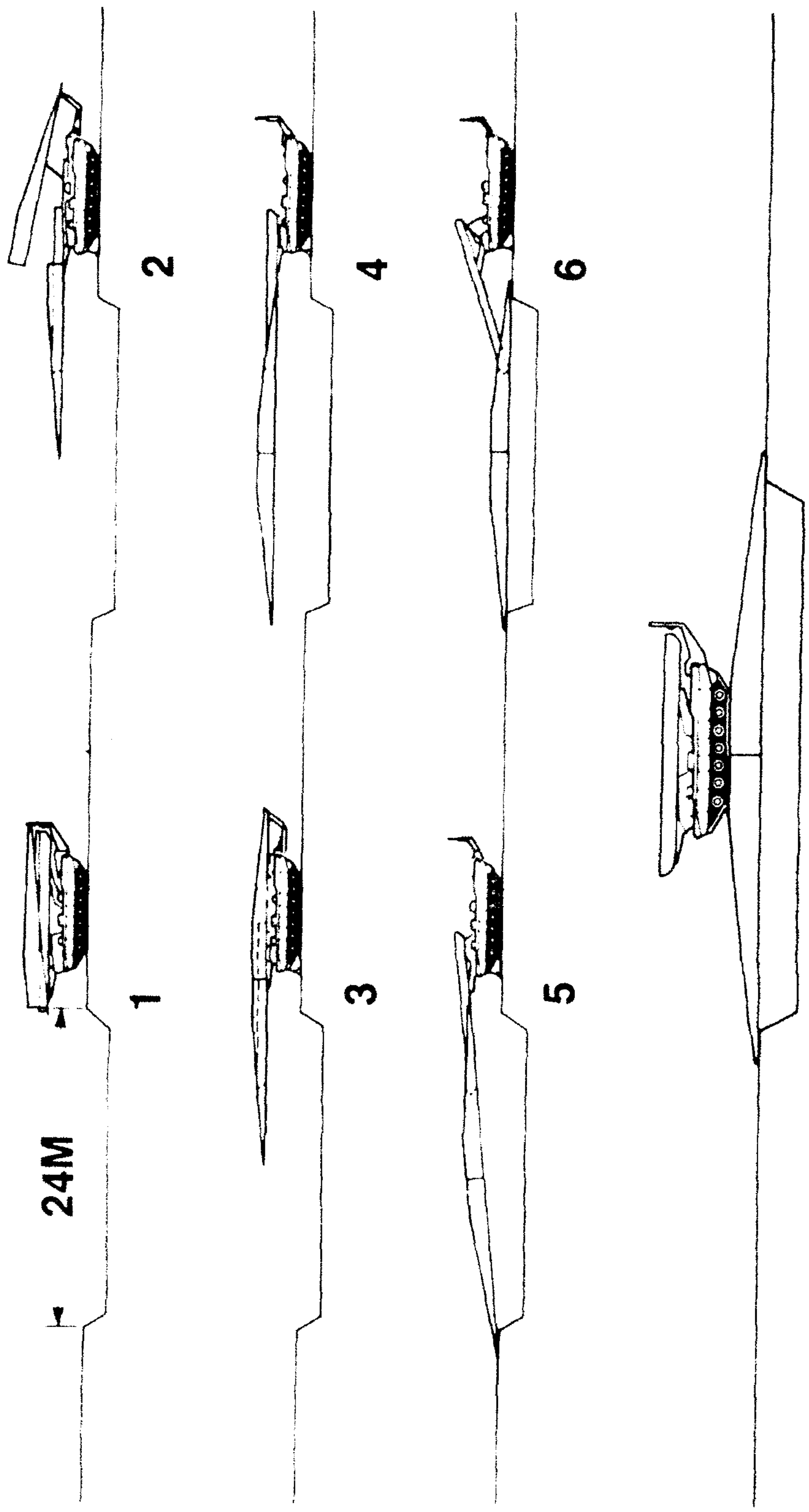

Figure 2d. Leguan HAB Launch Procedures

Durability Requirement

The nature of the test we are undertaking is an evaluation test, that is, it is a "met/not met" test of the HAB bridges against the durability requirement as stated in the HAB Required Operational Capabilities (ROC) document (ref 1). The HAB durability requirement as delineated in the ROC is:

"The bridge durability requirement is 5000 MLC 70 vehicle crossings [.]" [1]

While the simple definition in the Required Operational Capabilities (ROC) document doesn't specify whether the total number of crossings must be accomplished under a variety of spans and/or under a variety of bank conditions, you will see that the study group has considered variations of span and bank conditions in making an appropriate test. The group referred to resources such as the Operational Mode Summary/Mission Profile (OMS/MP) and the field experience of the Armored Vehicle Launched Bridge (AVLB) to consider all effects that can reasonably be encountered by an assault bridge in its 20 year life.

Durability Failure Definition

It is important that we use a common definition of a durability failure. The definition used by the Test and Evaluation Command (TECOM) evaluator is as follows:

> *"A malfunction that **precludes further operation** of the bridge and is great enough in cost, safety, or time to restore that the bridge must be replaced or rebuilt. Durability failures are failures that **are uneconomical** to repair, failures whose repairs require system replacement or rebuild at the **General Support (GS) or Depot level** of maintenance, or the onset of **suddenly increasing failure rate** indicative of overall system wearout."*

The definition shows that a durability test is not concerned with routine failures that are repaired at the Direct Support (DS) or lower levels of maintenance. Hose breaks, deck wear, and failures in parts that are replaceable at the lower maintenance shops are not durability failures. These non-durability failures are thoroughly addressed in other aspects of bridge testing. Durability failures are only those failures that are serious structural problems that cause a large cost or safety concern.

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[1] *Military Load Class (MLC) 70 is for most practical purposes a 70 ton vehicle load. For the HAB, the vehicle of primary concern is the 70 ton Abrams tank.*

Durability Testing

Let us step back for a little more background on why research into an alternate test method was done. We know what the durability requirement is, and we have agreed on what a durability failure is, now let us discuss why we might want to consider doing the durability testing in a different manner.

PURPOSE OF DURABILITY TESTING

The purpose of durability testing is to gather data to support an assessment of whether a bridge meets the durability requirement.

CURRENT TEST METHOD FOR HAB

The method currently planned to assess durability of the HAB bridges is to emplace a single bridge over a full span gap and run the crossing vehicle over it 5000 times. These crossings are done per the mission scenario described in the ROC (ref 1) which consists of driving the launch vehicle, with the bridge in the transport mode, for a few miles, approaching the launch site, launching the bridge, allowing 70 crossings by crossing vehicles, retrieving the bridge, and beginning the cycle again. A mixture of bank slopes is used throughout the total number of 5000 cycles. Only one bridge is used because of the limited number available. If no durability failures occur, per the definition stated earlier, then the assessment can be made that the requirement has been met.

It should be recognized that the first 2000 crossings are performed for assessments other than durability. This means that 2000 actual crossings will be done regardless of a durability assessment and are not candidates for replacement by an alternate test method.

WHY RESEARCH ALTERNATE TESTING?

Cost savings is the principle motivation for trying to discover alternate methods. The expense of running a 3000 vehicle crossing test at APG using 70 ton Abrams tanks is estimated as follows:

3000 Tank Crossings at APG (up to 3 bridges, 12 weeks)	
Operating and Maintenance Expenses	$ 275 k
Test Personnel/Operators	$ 50 k
	$ 325 k
Hanger Test at Belvoir (3 bridges, 9 weeks)	
Equipment Costs (operating and capitalization)	$ 60 k
Test Engineers and Support Personnel	$ 50 k
	$ 110 k
Potential Savings	**$ 225 k**

Recent Department of the Army (DA) policy has directed that simulation test methods should be used whenever possible. It is widely recognized that with the trend in testing budget reductions, durability testing by simulation may be the only option available in the not-too-distant future. Field tests may be unfunded, therefore limiting the choice to simulation or no test. This is not the case with the current HAB program however.

For the HAB program, 3000 field crossings are planned for a later phase of testing. Following the 3000 crossings the durability assessment can be made. Due to the affordability restrictions of testing three different bridge designs, the tank crossings cannot be done during this phase of testing and thus the durability assessment will not be contributing information to the selection between the three candidate designs. If simulation is an acceptable test, the durability test could be performed on all three designs in an affordable manner by a combination of 2000 actual crossings and 3000 simulated crossings. With 5000 equivalent crossings being done during the current phase of testing, the durability assessment could contribute data to the downselect decision.

How to Simulate Crossings

Now that we have made the case for why an alternate test method is needed, we can discuss how simulating crossings can be accomplished. At the point in government testing when a bridge is ready to undergo durability testing, it has proven that it can withstand crossing loads and has experienced at least 2000 crossings. The purpose of the simulation test is to uncover design flaws that show up above 2000 crossings but less than the 5000 crossings requirement. A structural failure that would occur after many cycles, that didn't occur after one cycle, is known as a fatigue failure because it is caused by fatigue of components.

BACKGROUND ON FATIGUE

A component may fail after repeated stress loadings even if the stress never exceeds the yield strength of the material. Continued cyclic loading causes fatigue fractures that are progressive, beginning as minute cracks that grow to become large cracks, that can lead to fracture of the part or structure.

The behavior of a material (e.g. 7005 Aluminum) under repeated loadings can be evaluated in a fatigue laboratory test. A sample is loaded repeatedly from zero stress to a known stress, and the number of applications of that stress is counted until the sample fails. This procedure is repeated for different stress levels. The results of many of these tests can be graphed in what is called an S-N curve, as shown in Figure 3.

For any given stress level, say σ_p in Figure 3, the corresponding number of applications of the stress which will cause failure is known as the fatigue life. The fatigue life is just the number of cycles of stress required to cause failure.

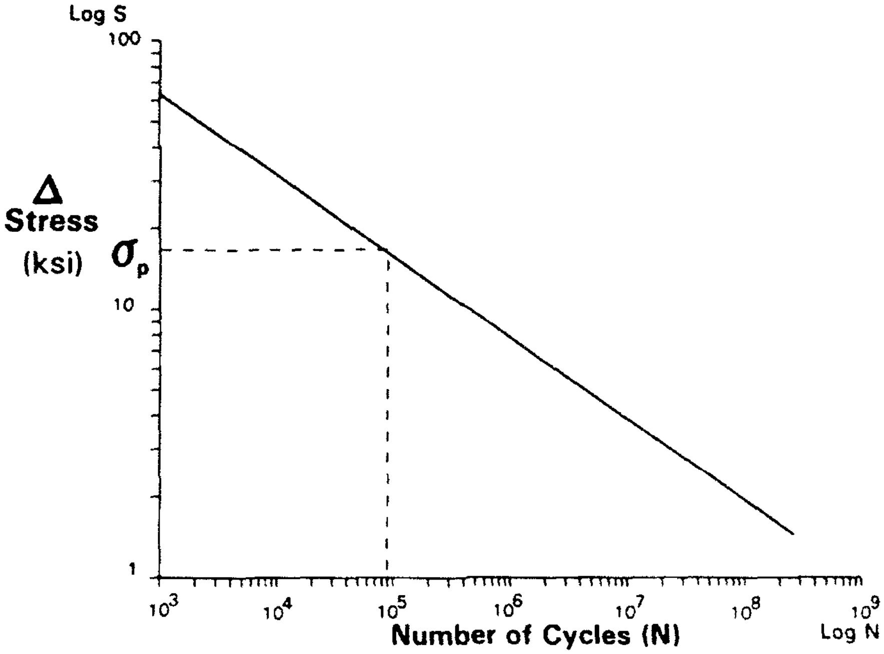
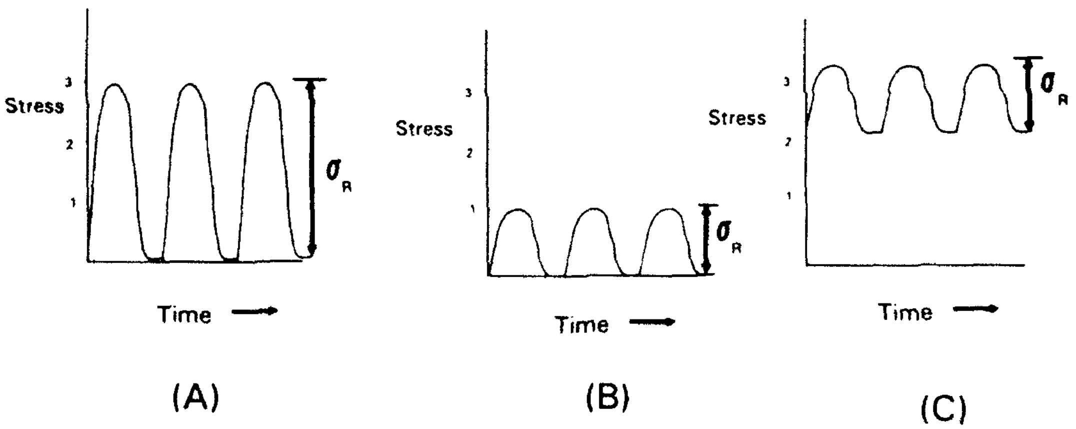


Figure 3. Results of Many Fatigue Tests for Aluminum

The ordinate on the S-N curve is "Change in Stress ($\Delta\sigma$)" signifying that the amplitude of the stress cycle is very important, see Figure 4.



Condition (A) causes more fatigue than Condition (B) or (C)

Figure 4. Stress Amplitude Effect on Fatigue

High stress fluctuations (high $\Delta\sigma$) cause the most fatigue. Low stress fluctuations (low $\Delta\sigma$) cause the least fatigue. The key to simulating crossings is repeating the high stresses in the bridge that are caused by tank crossings.

ANALYZE THE "EFFECTS" A BRIDGE EXPERIENCES IN FIELD OPERATIONS

The study group developed a list of all of the "effects" a bridge experiences in its normal operation, see Figure 5.

Various Bank Seat Conditions

- Side slope
- Racked slope
- Longitudinal slope
- Prepared/Unprepared abutments
- Variations of gap length from 0-24 meters

Load Spectrum

- Various crossing vehicles of various weights (max 70 tons)
- Accumulation of mud
- Eccentric loading when vehicle moves left or right on treadway
- Impact factor from fast moving vehicle slamming down on the bridge
- Vibrations caused by vehicle
- Vehicle braking, accelerating, or steering
- Shear stress reversals as a moving load crosses over a specific location
- Crossing from either end of the bridge
- Dead load of bridge

Sequence of Loading

- Sometimes heaviest loads precede light loads
- Sometimes light loads precede heavy loads

Launching/Retrieving

Environmental Effects

- Wind, rain, snow, temperature change, gravel, etc.

Figure 5. "Effects" Experienced by Bridge in Operational Use

Not everything that a bridge experiences contributes to fatigue, because not everything causes stress fluctuations.

Upon reviewing the list of effects, the study group separated the list into those effects which are unimportant to recreate beyond 2000 crossings (because they don't cause high stress fluctuations), and those which are important to simulate beyond 2000 crossings (because they may cause high stress fluctuations) see Figure 6.

Actual	No need to simulate	Simulate
Slopes (level, rack long, side)	Slopes (long.)	Slopes (level, rack, side)
Sequence of Slopes		Sequence of slopes
Span (≤ 24m)	Span (<24m)	Span (fixed at 24m)
Vehicle (MLC 10, 30, 60, 70 T)	Vehicle (<70 T) and wheeled)	Vehicle (70 T)
Speed (≤ 10 mph)	Cycle time	Impact factor
Launch and retrieve cycle	—	L/R cycle
Braking/Steering	Braking/Steering	—
Environment (mud, ice snow, gravel, wind, temperature.)	Environment	—
Dead load	—	Dead load

Figure 6. Effects to Simulate

THEORY OF CROSSING SIMULATION

After determining what to simulate, we worked to create a practical method of simulation. Remember that the key to simulation is recreating the stresses that the bridge experiences in operation. From strain gage data taken during actual tank crossings, we have a measure of how a tank crossing stresses the particular bridges we are interested in. When we apply loading to the bridge under the load frame, we will recreate the strains, therefore the stresses, experienced by the bridges in the field.

The stresses in the bridge caused by the tank crossing are directly proportional to the bending moments applied to the bridge by the tank. Recall the formula for bending stresses:

$$\sigma_b = \frac{MC}{I}$$

where: M = bending moment
C = distance from neutral axis
I = moment of inertia

C and I are built into the equipment at the time of manufacture and cannot be altered. So at any position along the length of the bridge, σ_b varies directly with M. By replicating the moments on the bridge caused by a tank crossing, we replicate the stresses in the bridge caused by a tank crossing.

Figure 7 illustrates the "crossing moments" applied by the tank. The high moments move along with the vehicle (see parts A, B, and C on Figure 7) with the highest moments occurring when the tank is at midspan. An envelope of maximum moments can be drawn (see part D of Figure 7). It is this envelope of moments we are trying to match in the simulation.

Figure 8 shows how loading the bridge using the load frame apparatus, at three carefully chosen positions, can recreate the crossing moments envelope with quite good fidelity. Creating the crossing moments in the bridge creates the stresses throughout the bridge exactly identical to the stresses caused by a tank crossing.

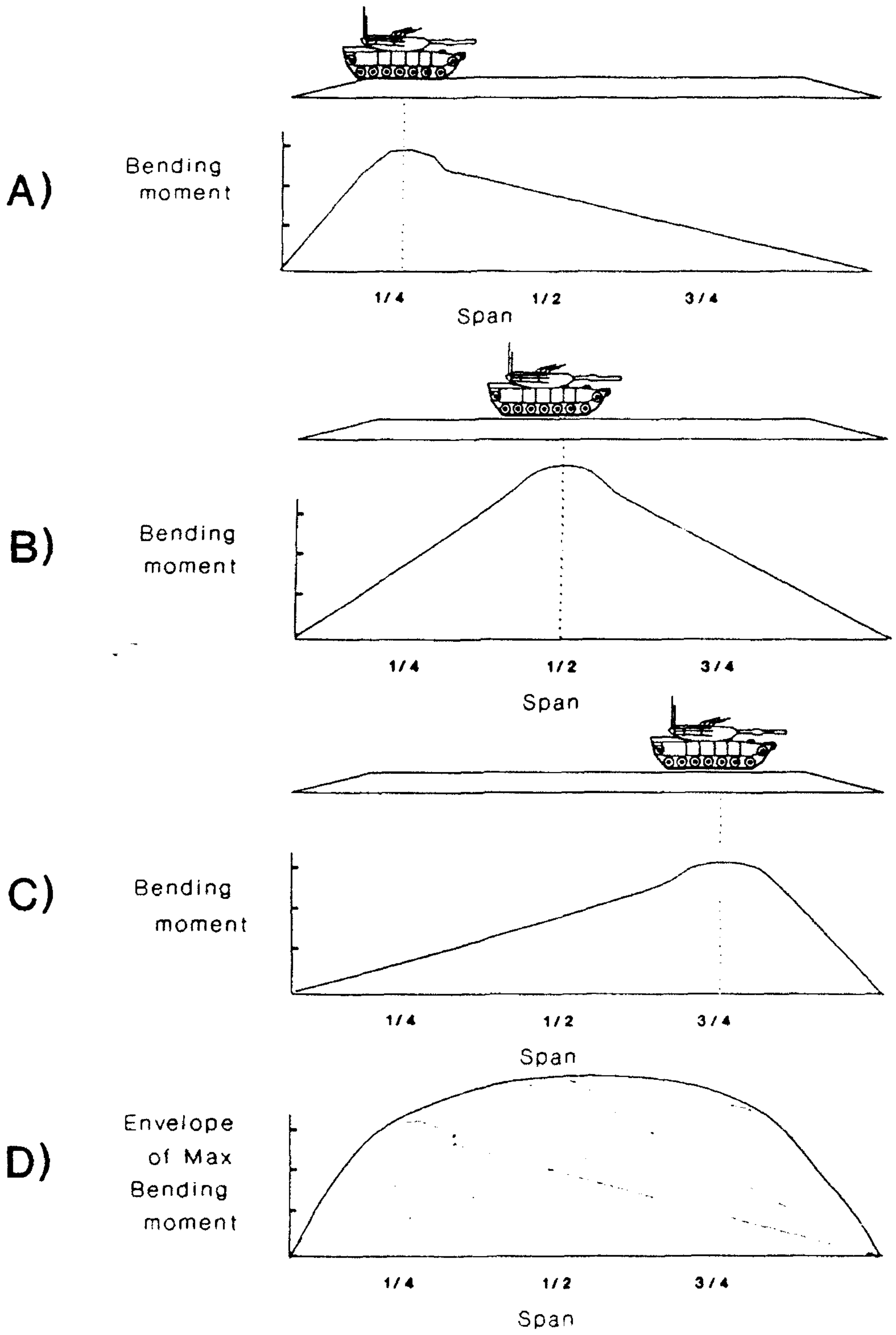


Figure 7. Bending Moments from Crossing Vehicles

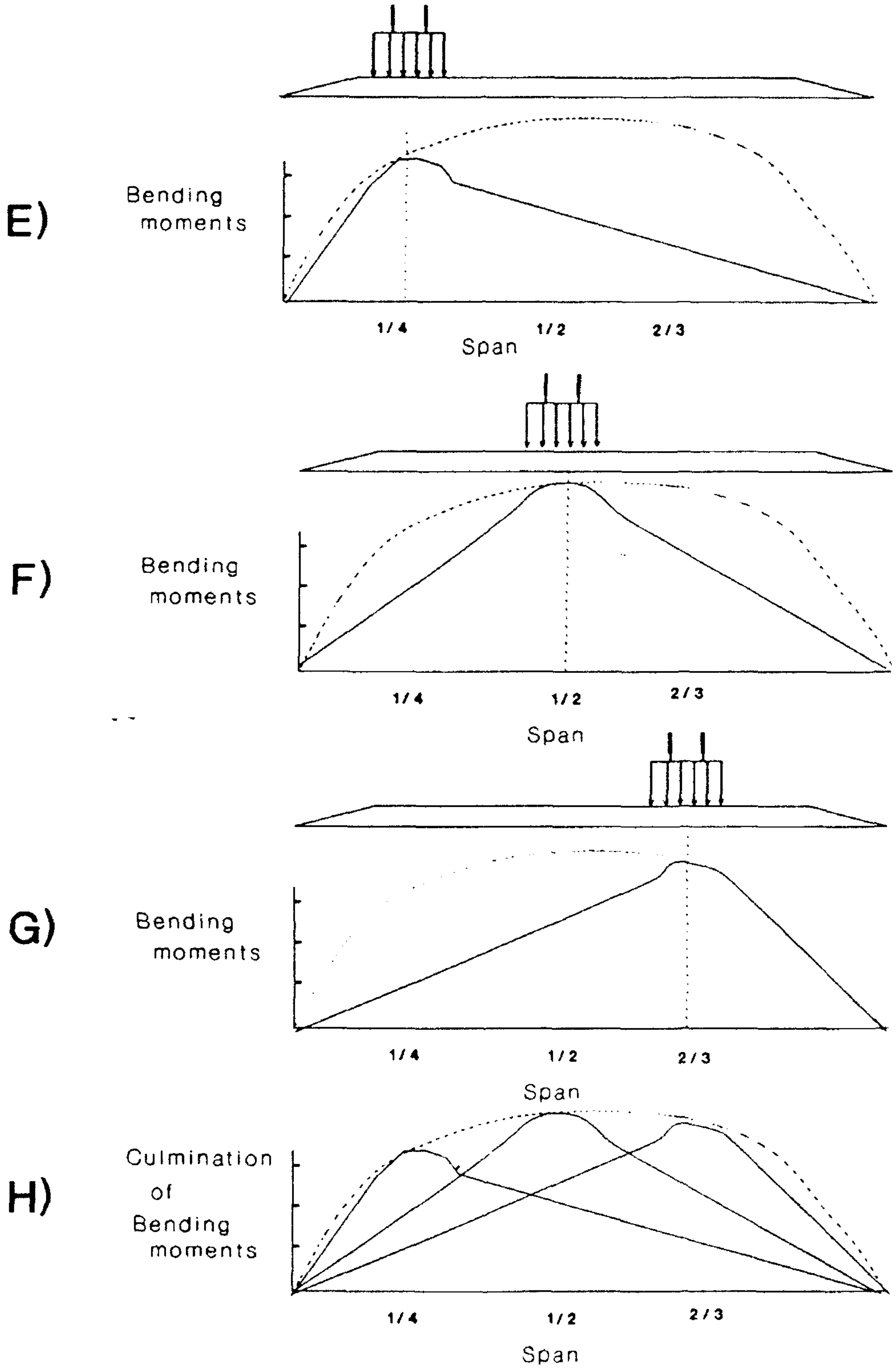


Figure 8. Bending Moments from Loading Apparatus

Proposed Test Set-Up

The suggested load placement locations are shown in Figure 9. Figure 9 is drawn to scale thus illustrating the extent of coverage that can be achieved by loading at the 1/4 span, 1/2 span, and 2/3 span positions. Recall that the bridge has symmetrical fabrication to the left and right of midspan. Symmetry of bridge construction means that the bridge components that are missed at the portion of the bridge between the 1/4 span loading position and 1/2 span loading position are loaded when testing identical components that are at the 2/3 loading position.

The proposed test uses the bridge that experienced the 2000 field crossings at APG and applies and additional 9000 loadings (3000 loadings at each of three positions described in Figure 9). The 9000 loadings equate to between 3000 and 5000 equivalent crossings as will be explained later in this research paper.

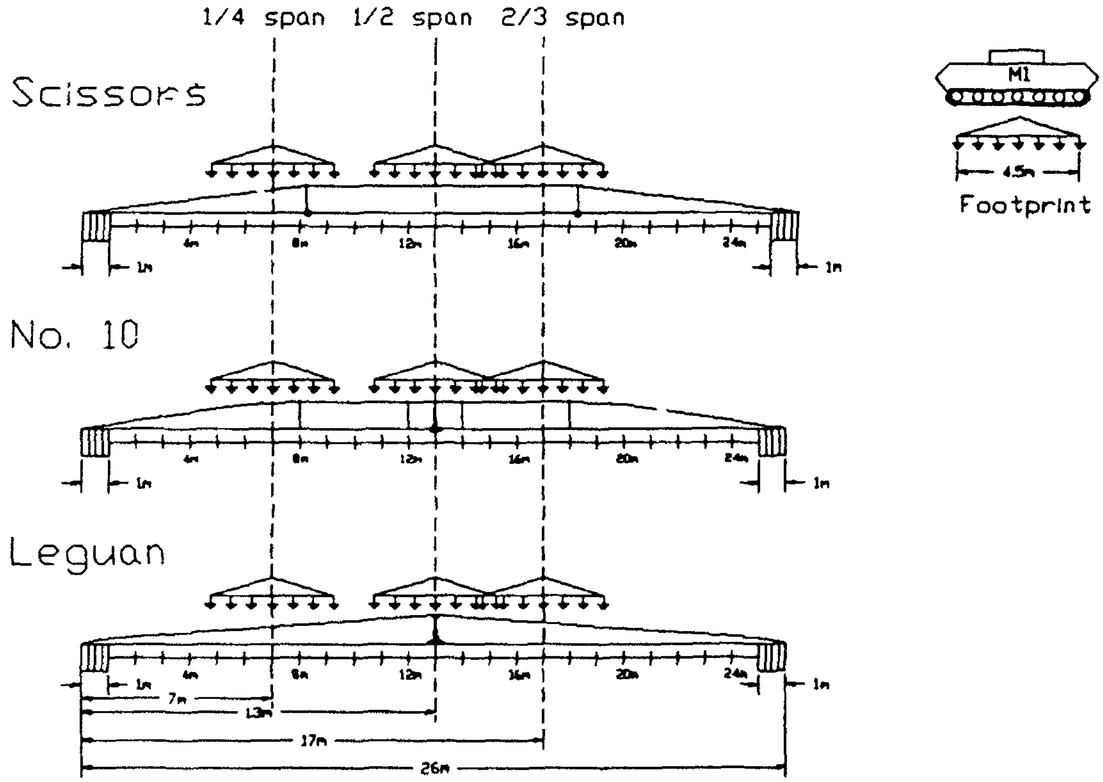


Figure 9. Load Placements

A mixture of bank conditions and eccentricity is suggested for the proposed test to account for certain "effects" listed in Figures 5 and 6. The suggested mixture is shown in Figure 10. Bank conditions and eccentricity are created in the lab vice simulated. Bank conditions are created by the supports used to place the bridge under the load frame. The bank supports can be varied throughout the test as necessary. Eccentricity is created by offsetting the load to one side of the bridge.

Actual Field Crossings: 2000

Simulated Crossings: Total of 9000 loadings,
3000 loadings in 3 positions as follows,

1/4 Span position	**1/2 Span position**	**2/3 Span position**
3000 Total loadings	3000 Total loadings	3000 Total loadings
2000 Level	2000 Level	2000 Level
1000 Centric	1000 Centric	1000 Centric
500 Left Eccentric	500 Left Eccentric	500 Left Eccentric
500 Right Eccentric	500 Right Eccentric	500 Right Eccentric
500 Side Slope	500 Side Slope	500 Side Slope
250 Right Side Slope	250 Right Side Slope	250 Right Side Slope
250 Left Side Slope	250 Left Side Slope	250 Left Side Slope
500 Racked	500 Racked 500 Racked	

Figure 10. Loading Pattern

Realism in Loading

Since we have strain data from the field tests, we are able to repeat the strains experienced at particular loading points just as the tank crossing at 10 mph created stresses at those loading points. This is the key to the authenticity of the test. By recreating strains, we remove the subjectivity from the decision of how much load to apply. The load will likely be different for each bridge design at each load placement position because different bridge designs act differently under vehicle crossings. By recreating strains, we do not unnecessarily "punish" one bridge design by applying the "worst case" load.

The Launch/Retrieve (L/R) cycle can be recreated in the lab if necessary. On an appropriate periodic basis, the launcher can be connected to the bridge so that a retrieval and launch can be performed, just as it was done in the field. The literature (ref 7) shows that L/R stresses may be an insignificant contributor to bridge fatigue because of the relatively low ratio of L/R per crossings (i.e. one L/R per 70 crossings). A simple calculation can be done to determine if the L/R cycle is necessary for the simulation test. If the stress from a retrieval is not at least one half of the stress from crossing {i.e. $|\sigma_{L/R}| > |{}^1/_2\, \sigma_{crossings}|$ } then the L/R cycle is unimportant to the simulation. The strain data available from the field tests is sufficient to determine the stresses from L/R and crossings.

How 9000 Loadings Compares to 3000 Tank Crossings

An ideal simulation test would create exactly 3000 equivalent crossings to combine with the 2000 field crossings, summing to make a test of exactly 5000 equivalent crossings to evaluate the bridge against the 5000 crossing requirement. Our research has discovered that it is not possible to attain exactly 3000 equivalent crossings through the use of the load frame apparatus. What can be achieved is a minimum of 3000 crossings and some extra crossings that we believe are not enough to be unreasonably strict on the bridge.

Creating the minimum 3000 equivalent crossings is done by cyclic loading from 0 to 70 tons[2] 3000 times at each of the three loading positions shown in Figure 9. This loading will closely recreate the moment envelope throughout the length of the bridge as discussed earlier in Figures 7 and 8. Figure 11 shows a more precise moment-to-span drawing.

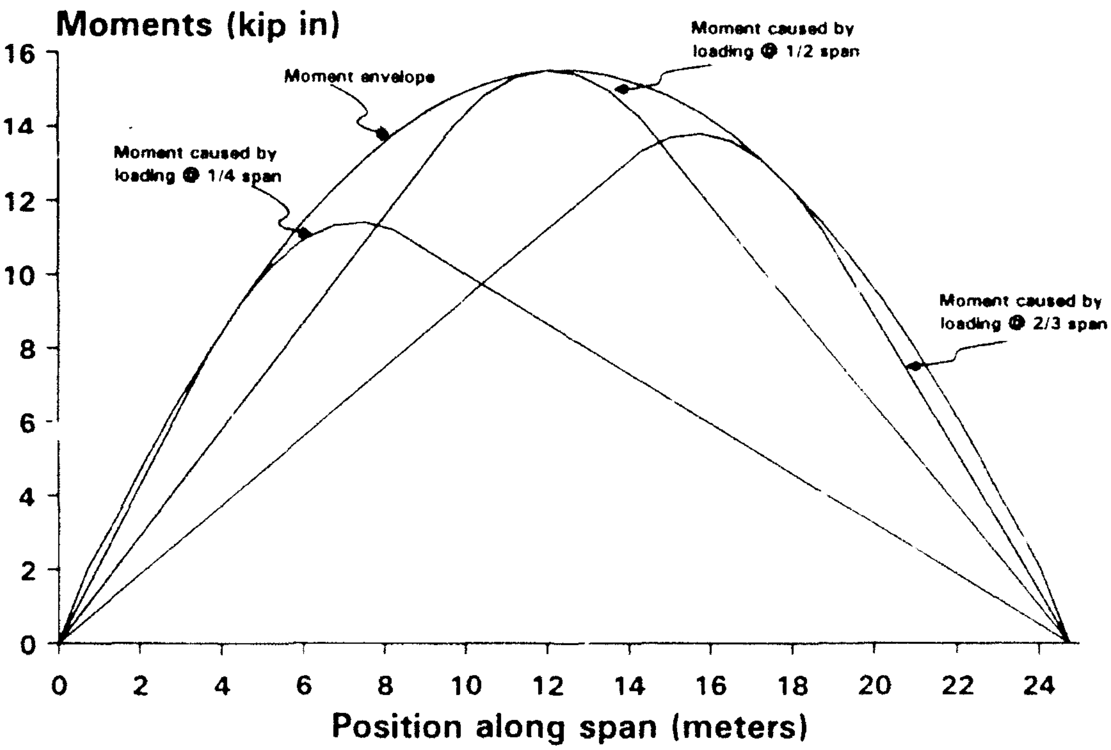


Figure 11. Moment Curves for Crossing Simulation

[2] *Load applied will be more than 70 tons to recreate strains found in field tests.*

Extra crossings occur because of the overlapping of the three load position moments curves. Let us examine the effect at the 1/4 span position for further clarification. At 1/4 span, 3000 full stress cycles will be applied by the load apparatus when it is at 1/4 span. Additional stress cycles (of lower magnitude) are caused at 1/4 span when the load apparatus is placed at the 1/2 span position. Further stress cycles (of even lower magnitude) are caused at 1/4 span when the load apparatus is placed at the 2/3 span position. Lower stress means much lower fatigue effect as explained by fatigue theory.

Empirical data shows that for aluminum, the S-N curve slope varies from 1/3 to 1/4.5 depending on the stress concentrations in the test samples (ref 5), see Figure 12. To be the most conservative, we will assume a slope of -1/3 applies to military bridges.

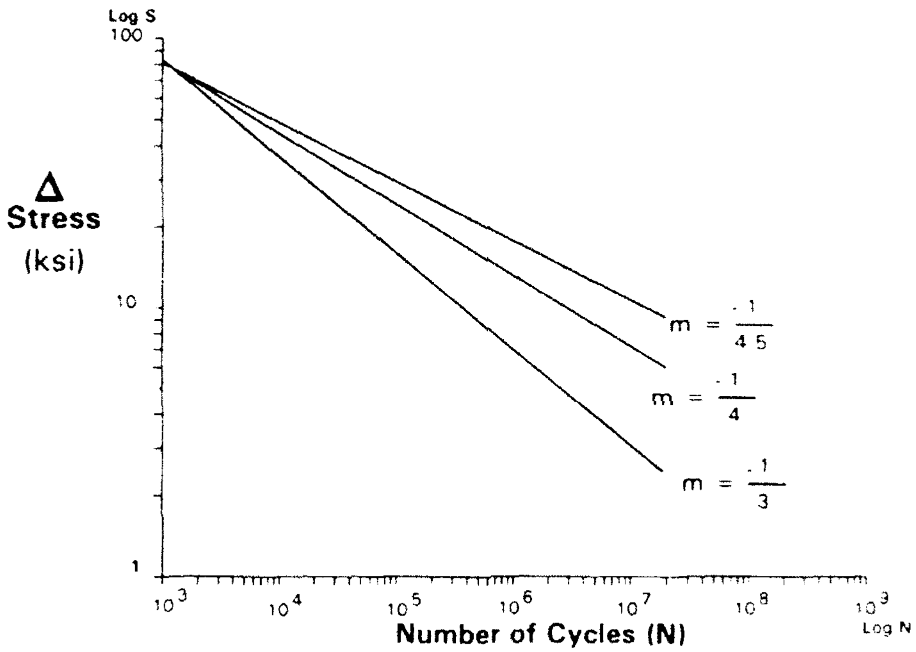


Figure 12. S-N Slopes for Aluminum

Because the ordinate and abscissa on the S-N curve are both logarithmic scale the following relations hold true.

$$\log S = m \log N + \text{Log } C$$

where S = stress range
m = slope constant
N = fatigue life defined as the number of cycles to failure corresponding to a particular stress range.
C = intercept constant

$$\log S = \log N^m + \mathrm{Log}\, C$$

$$S = N^m \times C$$

$$\frac{S}{C} = N^m$$

$$\left(\frac{S}{C}\right)^{1/m} = N$$

For aluminum alloys the slope constant lies between -1/3 and -1/4 depending on the fatigue classification of the structural detail, the more sensitive to fatigue the detail the lower the number (see Figure 12). If it is desired to quantify the effect of a change in stress range on fatigue life, the preceding equation can be rewritten in ratio form as

$$\frac{N_2}{N_1} = \frac{\left(\frac{S_2}{C}\right)^{1/m}}{\left(\frac{S_1}{C}\right)^{1/m}}$$

$$= \left(\frac{S_2}{S_1}\right)^{1/m}$$

Taking, as an example, a stress range ratio of 1/2 ($S_2 = 1/2\ S_1$) and a slope constant of $m = -1/3$, then substituting into the above equation yields

$$\frac{N_2}{N_1} = \left(\frac{S_1}{2S_1}\right)^{-3}$$

$$= 8$$

This formula tells us that a reduction in stress results in a cubed increase in fatigue life or a cubed reduction in fatigue effect. For example, reducing the stress by 1/2 results in a fatigue life increase of $(1/2)^{-3} = 8$. This means that 8 times the life can be expected at the lower stress, or said another way, the reduced stress had only 1/8 the fatigue effect of the higher stress. An illustrative example is shown in Figure 13.

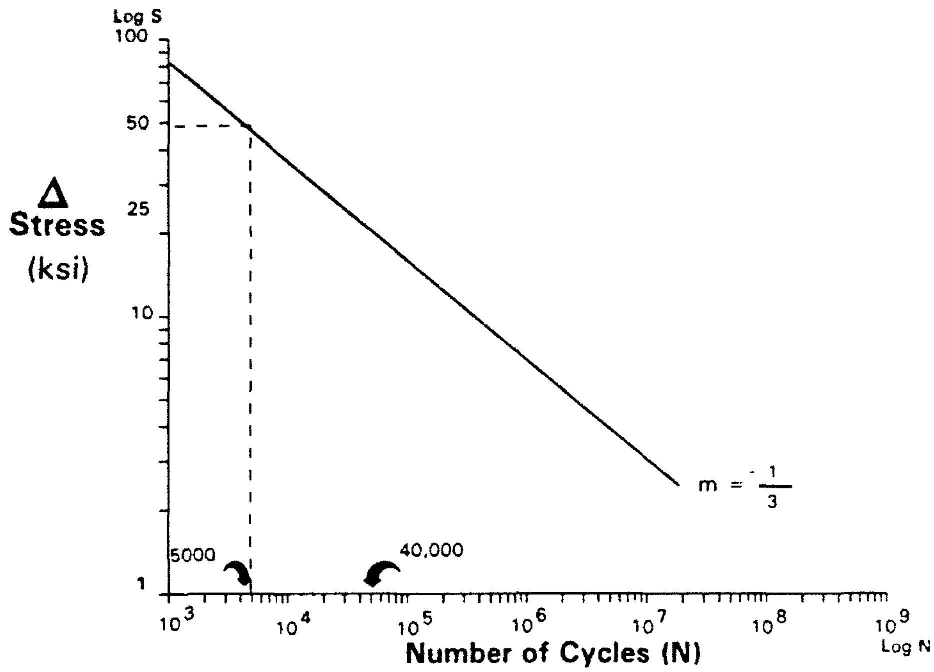


Figure 13. Reduction in Stress Causes Increased Fatigue Life

By this method, a reduction in stress can be converted into an equivalent number of crossings. If a stress cycle of 0-20 ksi represents one crossing in Figure 13, then a stress cycle of 0-10 ksi would represent 1/8 of a crossing. Recall from earlier discussions, that crossing stresses in a bridge are directly proportional to the moment applied. Equivalent crossings are derived from the moment values represented on Figure 11.

Figure 14 shows the calculated values of the equivalent number of crossings that a bridge will experience after undergoing 2000 field crossings then loading at the three proposed locations.

	LOADING POINT		
	1/4 Span	**1/2 Span**	**2/3 Span**
Equivalent crossings effect at			
1/4 Span	3000	512	232
1/2 Span	1211	3000	1829
2/3 Span	346	1132	3000
Simulated Crossings	4557	4644	5081
Field Crossings	+2000	+2000	+2000
Total Equiv Crossings	**6557**	**6644**	**7081**

Figure 14. Calculated Equivalent Crossings

The total equivalent crossings will range from 5000 at a minimum to approximately 7000 at a maximum. For a criteria of 5000 required crossings, 7000 calculated equivalent crossings is not an unreasonably strict test.

Other Thoughts

IMPORTANCE OF THE SEQUENCE OF LOADING

The loadings described in Figure 13 should be applied in a mixed order, e.g. 500 loadings at 1/4 span, then 500 loadings at 1/2 span, then 500 loadings at 2/3 span. Performing all loadings at 1/4 span, then doing all loadings at 1/2 span, followed by all loadings at 2/3 span, will give a different effect to the bridge than mixing the positions.

SEPARATING THE TREADWAYS

During our research we considered separating the treadways for the simulation test in order to have more samples, thus a higher statistical significance. Several weaknesses were discovered. The bridges involved in the test must have identical treadway sections in order for the method even to be feasible. The Leguan bridge design uses a different fabrication for the inner bottom chord, and outer bottom chord because the outer chord is designed to withstand higher stresses. Separating the treadways would likely cause the inner chord to undergo higher stress, thus causing more fatigue than would occur in the field. A second problem with separating the treadways is the assumption that the stress transfer between the treadways is negligible. Field data causes us to suspect that in some bridge designs the stress transfer is not small and should not be neglected.

Recommendations for Further Research

COMPONENT TESTING

Bridge durability may be enhanced through component testing and subsystem testing prior to fabrication.

PERIODIC OVERLOADING

The literature suggests that periodic overloading can be beneficial to fatigue strength because in certain circumstances the overload has shown a crack arresting effect.

Conclusions

1. Bridge stresses caused by tank crossings can be reproduced using a loading apparatus.

2. Repeated cycling of the loading apparatus in various predetermined positions on the bridge will fatigue structural members of the bridge just as they would be fatigued under vehicle crossings.

3. For a bridge durability assessment, a viable test alternative to a bridge undergoing 5000 field crossings is for the bridge to undergo 2000 field crossings plus 3000 equivalent crossings under the loading apparatus.

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